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RESEARCH ARTICLE

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Exploring the impact of population density on journey-to-crime in cases of stranger sexual assault and stranger homicide

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Abstract

The purpose of this research is to further understanding of how environmental factors impact on the distance an offender travels from their home to their crime scene - the so called 'journey-to-crime' (JTC.). Currently, Geographic Profilers rely on relatively generic JTC research to form inferences about the likely distance travelled by an offender, and may be missing the opportunity to make a more bespoke assessment which takes these factors into account. 1186 cases of female stranger sexual assault (Study 1) and 124 cases of stranger homicide (Study 2) were analysed. Euclidean measurement of distance was provided from the offender's recorded home to 3 crime site locations: (1) the initial contact with victim, (2) the assault/murder, and (3) the victim release/body disposal. Each crime site location was coded according to: (a) population density and (b) urban or rural. Initial analysis examined the median distance travelled from an offender's residence to the three different crime site locations. Significant findings for stranger sexual assaults indicated that the initial contact location was significantly further from an offender's residence compared to the sexual assault and victim release location. This was not replicated for stranger homicide offences. Both sexual assault and homicide cases revealed that the distance travelled to the

'initial approach' location did not differ according to population density, or whether the location was urban or rural. Regarding 'sexual assault' locations, offenders were found to travel significantly further from their home to attack their victim in low population density and rural areas. Results showed that both sexual assault and homicide offenders travelled significantly further from their home to the 'victim release/body disposal' site in low population density areas and rural areas. These findings have important, practical applications for investigations, allowing Geographic Profilers to provide more bespoke inferences about an offender's journey to crime.

KEYWORDS
geographical profiling, investigative psychology, offender profiling and behavioural investigative advice

1 | INTRODUCTION

During the investigation of complex and serious crimes, such as stranger homicide and sexual offences, Senior Investigating Officers (SIO) may request empirically based advice from Behavioural Investigative Advisers and/or Geographic Profilers (Cole & Brown, 2011). Specifically, Geographic Profilers may assist by determining the likely area in which an offender resides or possesses some form of 'anchor point' (Rossmo, 2000), with reference to the temporal and spatial patterns of a crime or series of crimes (Knabe-Nicol & Alison, 2011). Providing empirically based evidence that can assist Geographic Profilers in providing accurate advice to police is essential (Knabe-Nicol & Alison, 2011).

Despite research on Journey to Crime (JTC) having made substantial progress over the years, the literature still lacks a thorough understanding of how the environmental features of an area may impact an offender's JTC (Akerman & Rossmo, 2014). Currently, Geographic Profilers at the UK's National Crime Agency (NCA) utilise empirically based evidence that takes little account of these factors. Improved understanding of how environmental factors impact JTC will enable a more tailored approach to be taken, and contribute to improving the inferences made about an offender's JTC in sexual assault and homicide offences. Therefore, using data provided by the NCA, the current research aims to investigate the impact of population density on JTC in cases of stranger rape and homicide.

1.1 | Journey to crime (JTC)

JTC research demonstrates that, on average, offenders do not appear to travel very far to commit their crimes. For example, median distances travelled between an offender's home and the scene of a rape have been reported of around 2.5 km (Canter & Larkin, 1993; Rossmo et al., 2004; Santtila et al., 2007) and between an offender's home and the scene of a homicide of 3.9 km (Häkkänen et al., 2007). Other studies of sexual homicide show much a shorter JTC of 1.29 km to initial contact site and 1.8 km to body disposal sites (Martineau & Beauregard, 2016).

JTC research often points to evidence of 'distance decay'—as the distance from an offender's home increases, the probability of them committing a crime at that location decreases (Chopin & Caneppele, 2018). Distance decay is supported by Zipf's (1949) 'least effort' principle whereby individuals invest the least energy necessary to perform

a desired activity. Researchers have however indicated that the proximate areas encircling offenders' residences (i.e. distances of '[a] few blocks') are targeted less frequently than areas slightly further away (Rhodes and Conly (1981)). These areas are termed *buffer zones* (Brantingham & Brantingham, 1981; Laukkannen & Santtila, 2006).

Some researchers contest the notion of using distance decay research in explaining the distance travelled by individual offenders, as research findings are often concluded from aggregate data, therefore estimates may be jeopardised by an ecological fallacy (Townsley & Sidebottom, 2010; Van Koppen & De Keijser, 1997). For instance, offenders may be influenced by other environmental factors, their socio-economic status (Rossmo, 2000), or varying degrees of individual differences with regard to their willingness to travel (Andresen et al., 2014).

An offender's JTC can also be theoretically expressed through Crime Pattern Theory (Brantingham & Brantingham, 1981). Crime Pattern Theory proposes every individual has their own awareness space, formed as part of their routine activities, for example, the route from home to work, forming to create a 'mental map' (Rossmo, 2000). Therefore, crimes takes place within an offender's awareness space, where opportunity meets familiarity (Brantingham & Brantingham, 1981; Rossmo et al., 2012).

1.2 | Population density

A review of the literature presents widespread research on JTC, yet there is little research that compares population density to the distance travelled by offenders. Population density can also define whether an area is 'urban' or 'rural'. This research categorises 'urban' as physical settlements with a population of over 10,000, and 'rural' as physical settlements with a population of under 10,000 (Government Statistical Service, 2011).

Urban and rural areas differ on several factors, for example, over 60% of people living in urban areas are able to access employment, schools, GPs, supermarkets and town centres 'within a reasonable time' compared to 48% of people living in rural areas in England (Pateman, 2011). Consequently, awareness spaces (within which offenders tend to commit their crimes), in general, are larger for those living in rural rather than urban areas (Pateman, 2011). Differences are also evident in crime rates, including rates of sexual offences and homicides, which are higher in urban areas compared to rural (Office National Statistics, 2018). One explanation for this difference is population density; although urban areas in England account for only 20% of the land area, they house 80% of the population (Pateman, 2011). This explanation is supported by Shaw and McKay's (1942) Social Disorganisation Theory, which proposes that crime rates are higher in urban areas because of the larger population density, as well as factors such as more ethnic diversity, and more residential and economic disadvantage.

A higher population density means offenders do not have to travel as far because there are more opportunities to offend locally, that is, there is a larger available victim population (Ackerman & Rossmo, 2014; Glaeser & Sacerdote, 1999). However, Brueckner and Largey (2008) argue that individuals in urban areas are more cautious of others, and are more likely to take security measures (Bacares, 2014). Consequently, high population density areas may actually deter offenders (Bacares, 2014) and offenders may search out lower density areas (Brueckner & Largey, 2008). Before offending, individuals will consider the effort, rewards and costs associated with their options (The Rational Choice Theory, Cornish & Clarke, 1986), particularly the risk of being identified (Chopin & Caneppele, 2018). It is suggested that offenders living in urban, densely populated areas are able to travel shorter distances to become unrecognisable compared to less populated areas (Goodwill, van der Kemp & Winter 2013).

Of the limited research exploring the impact of population density on JTC for sexual crimes, findings have shown that offenders who assaulted a victim in an urban area travelled, on average, significantly shorter distances (Mean = 2.40 km) than offenders who assaulted victims in rural areas (Mean = 5.38 km, Warren et al., 1998). However, others have found no distinction between the rural and urban crime-sites chosen by the offender and their JTC (Rossmo et al., 2004).

Therefore, with somewhat inconsistent and limited research in relation to population density, further research is required. Furthermore, a limitation of previous research is that it has generally categorised locations into two distinct

categories, urban and rural locations (Newburn et al., 2007), with the majority of research focussing exclusively on urban areas (e.g. Avakame, 1997; Ruperal, 2004), or rural areas (e.g. Häkkänen et al., 2007), rather than examining the differences between them and the fluctuations in population density across smaller geographical areas. The available research, to date, has therefore failed to provide a comprehensive and adequate overview of the impact offence locations' population density has upon offenders' JTC.

1.3 | Rationale and hypotheses

Despite JTC research and theories pulling together complex cognitive processes, they do not delve deeper into how environmental factors impact JTC. Furthermore, they tend to focus upon two sites: the offender's home and a single crime-site. Whilst a single crime site may be valid for crimes such as burglary, this may not be the case in sexual crimes or homicides with a mobile victim (Beauregard et al., 2010). In these cases there may be multiple crime site locations, including where the offender and victim first had contact, where the assault (or homicide) took place, and where the victim was released, or the body was disposed of. Identifying the different locations within a crime is important as analysing the different crime-sites can give information regarding offender behaviour and familiarity with a location (Hewitt et al., 2012).

This study will expand upon previous research by exploring the distance travelled to 3 crime site locations, in addition to contributing to the research exploring how environmental factors of crime-sites may impact JTC (Akerman & Rossmo, 2014). Therefore, the current study sought to explore the distance travelled from the offender's residence to the three key sites of the offence, being: (1) the initial contact location, (2) attack location and (3) victim release/body disposal location and whether any differences within these distances emerged within stranger sexual assaults and homicides. Geographic Profilers form inferences about the likely distance travelled by an offender, and may be missing the opportunity to make a more bespoke assessment which takes these factors into account. Furthermore, this study aims to examine the impact of population density on JTC in cases of stranger sexual assault and homicide. By doing so, it will enable Geographic Profilers to apply a more tailored approach based on the characteristics of a crime-site location and provide more informed inferences relating to an offender's JTC.

Based upon a review of the literature it was hypothesised that:

1) The greater the population density of a crime site, the shorter the distance travelled to commit the offence will be.
2) Urban crime sites will have significantly shorter JTC distances than rural crime sites.

2 | METHOD

2.1 | Sample

Data was archival, provided by Serious Crime Analysis Section (SCAS) at the National Crime Agency. SCAS manages ViCLAS, a national database held to conduct comparative case analysis on cases of stranger rape, murder and abduction. All police forces in England and Wales are mandated to submit data to SCAS for cases that meet the following criteria: stranger rape,[1] serious sexual assaults and motiveless or sexually motivated murder cases. All cases involved a single offender and if an offender had committed multiple offences, only information from their first offence was used to ensure distances were not biased by serial offenders (Canter et al., 2003).

2.2 | Study 1 sexual assault sample

There were 1186 male offenders with a mean age of 28.58 (SD = 9.79) all of whom committed stranger adult female rape, attempted rape or sexual assault in 2000–2019. There were 1207 victims with a mean age of 29.81 (SD = 15.20), there are more victims then offenders due to some offences involving more than one victim. The sample included offences from across England (*n* = 1027), Wales (*n* = 34) and Scotland (*n* = 125).

2.3 | Study 2 homicide sample

There were 124 male offenders with a mean age of 31.11, (SD = 10.09) all of whom had committed homicide against a stranger victim in 1990–2018. The Victims had mean age of 38.11, (SD = 22.00). The sample included offences from across England (*n* = 98), Wales (*n* = 5) and Scotland (*n* = 21).

2.4 | Design

This was a between-subjects design with two independent variables (1) population density (ONS codes 1–5) and (2) crime-site category (urban or rural) and one dependent variable of distance travelled from offender's residence. Distance in km was also used as a dependent variable comparing across the 3 crime locations (initial contact/attack and body release/disposal).

2.5 | Measures and variables

Distance travelled from the offender's residence to three crime sites (initial contact, assault/homicide location and victim release/body disposal site) was calculated by SCAS, and measured using Euclidean distance (i.e., 'as the crow flies'). There were cases when not all three locations were known, for example, in homicide cases it was not always known where the initial contact site was located. Therefore, analysis was only conducted on known locations, *n* values are included in Tables to indicate where data was/was not known. Euclidean distances, which are measured as a straight-line between two points, were used over Manhattan distances where two points are measured along an axis at right angles. This is due to grid-based street layouts not frequently beingencountered in the UK (Canter & Larkin, 1993; Rossmo, 2000) resulting in an over-estimation of distance in non-grid based layouts (O'Leary, 2011). The Office for National Statistics (ONS) classified population density utilising the Rural Urban Classification (2011) for England and Wales and the Urban Rural Classification (2016) for Scotland. Five population categories were provided by ONS from 1—being the least populated, to 5—the most densely populated (see Table 1).

Using the Government Statistical Service guidelines (2011) ONS coded crime-sites as 'urban' if the population density of the area was over 10,000, and 'rural' if the population density was below 10,000 (see Table 1).

TABLE 1 ONS population density categories and codes defined as urban or rural

ONS population density code	Urban or rural
1. Rural village	Rural
2. Rural town	Rural
3. Urban city	Urban
4. Urban minor conurbation	Urban
5. Urban major conurbation	Urban

2.6 | Statistical analysis

Histograms confirmed the data was non-parametric with a positive skew of distance travelled. Due to the level of overdispersion in the data and kms of distance not being classed as individual Benoulli trail decision points, regression analyses were deemed not appropriate for this dataset. Instead Kruskal–Wallis *H* tests assessed any significant differences between population density categories on the distance travelled by offenders to each crime-site, using asymptotic significance levels of 0.05. Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons was applied to correct for Type 1 errors for the pairwise comparisons in the Kruskal–Wallis *H* tests only. Statistical significance was adjusted to $p < 0.005$ level. Eta squared (η^2) effect sizes were calculated where 0.01 was a small, 0.06 a medium, and 0.14 a large effect size (Cohen, 1988).

Mann–Whitney *U* tests investigated if there were any differences in the distance travelled to urban and rural crime-sites using asymptotic significance levels of 0.05. Cohen's denoted *r* (1988) effect sizes were provided whereby 0.1 was a small, 0.3 a medium, and 0.5 a large effect size.

3 | RESULTS

3.1 | Study 1 sexual assault

3.1.1 | Distances travelled across the 3 crime site locations within stranger sexual assaults

When comparing the distanced travelled from an offender's residence to the 3 crime site locations (initial contact, attack, victim release), a Kruskal–wallis *H* test indicated a significant difference, $X^2(2) = 12.409$, $p = 0.002$. Post hoc tests indicated that the initial contact location was significantly further from the offender's residence (Mdn = 1.99 km, $p = 0.002$) compared to the attack location. The initial contact location was also significantly further from the offender's residence than the victim release site (Mdn = 1.64 km, $p = 0.036$). This indicates that both the attack and victim release location occur significantly closer to the offender's residence, compared to initial contact location, which is furthest from the offender's home.

When exploring the rural/urban location categories and the three stranger sexual assault crime locations there were no differences found. This was found for both the two-level coding of urban/rural: $X^2(2) = 5.043$, $p = 0.080$ and also for 5 categories of population density: $X^2(8) = 8.651$ $p = 0.373$.

3.1.2 | Initial contact location

A Kruskal–Wallis *H* test using the distance travelled against the 5 categories of population density found that Rural Village recorded a higher distance travelled for initial contact site (Mdn = 5.23 km) compared to all other population density categories (all <2.27) (Table 2), however, this was non-significant $X^2(4) = 8.07$, $p = 0.089$.

A Mann–Whitney *U* test also revealed the median distance travelled by offenders from their residence to initial contact sites in urban areas (1.4 km) and rural areas (2.01 km) was not significantly different, ($U = 28{,}562$, $z = -0.04$, $p = 0.971$) (Table 2).

3.1.3 | Attack location

The distance travelled to attack sites was significantly different amongst population density categories, $X^2(4) = 26.79$, $p < 0.001$, with a small effect size of $\eta^2 = 0.02$ (see Table 2). Post hoc analysis revealed offenders who assaulted their

TABLE 2 Distance travelled by sexual assault offenders from their residence to crime sites split by population density categories

	Initial contact location			Attack location			Victim release location		
Population density category	*N*	Median (km)	Range (km)	*N*	Median (km)	Range(km)	*N*	Median (km)	Range (km)
Rural village	22	5.23	0–104.86	46	6.73	0–107.60	36	5.23	0–107.60
Rural town	28	1	0–91.94	30	1.59	0–369.92	30	1.59	0–185.09
Urban city	506	1.62	0–471.54	497	1.38	0–471.54	506	1.49	0–471.54
Urban minor conurbation	88	1.93	0–235.78	83	1.28	0–77.80	87	1.36	0–77.80
Urban major conurbation	490	2.27	0–435.76	495	1.66	0–436.05	490	1.79	0–436.05
Urban	1081	2.01	0–471.54	1072	1.48	0–471.54	1080	1.61	0–471.54
Rural	53	1.48	0–104.68	79	4.45	0–369.92	69	2.38	0–185.09

victim in a Rural Village travelled on average significantly further (6.73 km) than offenders who assaulted a victim in a Rural Town (1.59 km, $p = 0.043$); an Urban City (1.38 km, $p < 0.001$); an Urban Minor Conurbation (1.28 km, $p < 0.001$) or an Urban Major Conurbation ($n = 1.66$ km, $p < 0.001$). There were no other significant differences.

When exploring the categories of rural and urban and distance travelled by offenders to assault sites, distances travelled to rural areas (4.45 km) were significantly greater than to urban areas (1.48 km), $U = 52{,}857.50$, $z = 3.69$, $p < 0.001$ (Table 2). This showed a small effect size of $r = 0.11$.

3.1.4 | Victim release location

The distance travelled to victim release sites was significantly different amongst population density categories, $X^2(4) = 12.67$, $p = 0.013$, with a small effect size of $\eta^2 = 0.01$ (See Table 2). Post hoc analysis revealed offenders who released their victim in a Rural Village travelled on average significantly further (5.23 km) than; offenders who released their victim in an Urban City (1.49 km, $p = 0.018$); an Urban Minor Conurbation (1.36 km, $p = 0.007$), or an Urban Major Conurbation (1.79 km, $p = 0.008$). No other significant differences were found.

Offenders also travelled significantly further to victim release sites in rural areas (Mdn = 2.38 km) compared to victim release sites in urban areas (Mdn = 1.61 km), $U = 43{,}603$, $z = 2.38$, $p = 0.018$ (See Table 2). This was a very small effect size of $r = 0.07$.

3.2 | Study 2 homicide

3.2.1 | Distances travelled across the 3 crime locations within homicides

When comparing the distanced travelled from an offender's residence to the 3 defined homicide locations (initial contact, murder and body disposal), a Kruskal–Wallis *H* test indicated a non-significant effect, $X^2(2) = 2.007$, $p = 0.367$. This indicates that for homicides the initial approach, attack (murder) and the body disposal all occur within similar distances from the offender's residence. Furthermore, comparisons of the three murder location sites were non-significant for the two-level coding of urban/rural: $X^2(2) = 0.808$, $p > 0.05$ and also for 5 categories of population density: $X^2(8) = 2.369$ $p > 0.05$.

3.2.2 | Initial contact location

Chi-Square analysis did not reveal any significant associations between the distances travelled by offenders to the initial contact site and the 5 population density categories, χ^2 (4) = 6.81, p = 0.146. Mann–Whitney U test also found no significant differences in distances travelled when initial contact sites were coded as Urban or Rural, U = 190.00, Z = 1.48, p = 0.138 (see Table 3).

3.2.3 | Murder location

Chi-Square analysis did not reveal any significant associations between the distances travelled by offenders to the murder site and the 5 population density categories, χ^2 (4) = 8.38, p = 0.079. Mann–Whitney U test found no significant differences in distances travelled when murder sites were coded as Urban or Rural (U = 551.00, Z = 1.53, p = 0.125) (See Table 3).

3.2.4 | Body disposal location

The distances travelled to body disposal sites were significantly different amongst population density categories, X^2(4) = 21.05, p < 0.001, with a large effect size of η^2 = 0.17 (See Table 3). Post hoc analysis revealed offenders who disposed of the victim's body in a Rural Village travelled on average significantly further (11.2 km) than offenders who disposed of the victim's body in an Urban City (0.9 km; p < 0.001) or in an Urban Major Conurbation (1.57 km; p = 0.011). No other significant differences were found (see Table 3).

Mann–Whitney U test showed that the distances travelled by offenders to body disposal sites in rural offence locations (8.30 km) were significantly further on average than the distances travelled by offenders to body disposal sites in urban offence locations (1.05 km), U = 1435.00, Z = 3.51, p < 0.001, with a medium effect size of r = 0.32. See Table 3.

4 | DISCUSSION

The current study investigated whether the population density of a crime location impacts the distance travelled by offenders in cases of stranger sexual assault and stranger homicide. The study examined distance travelled and

TABLE 3 Distance travelled by homicide offenders from their residence to crime sites split by population density categories

	Initial contact location			Murder location			Body disposal location		
Population density category	*N*	Median (km)	Range (km)	*N*	Median (km)	Range(km)	*N*	Median (km)	Range (km)
Rural village	3	14.19	2.78–91.42	4	6.11	2.78–14.19	10	11.22	2.78–171.01
Rural town	5	13.22	0.58–152.46	5	1.14	0.28–51.76	7	8.35	0.28–51.76
Urban city	33	1.07	0–206.29	33	0.94	0–206.29	53	0.90	0–206.29
Urban minor conurbation	5	3.39	0.28–15.94	5	3.53	0–17.27	10	2.58	0–17.27
Urban major conurbation	24	2.32	0–91.57	24	1.58	0–91.57	43	1.57	0–91.57
Urban	61	1.43	0–206.29	85	1.09	0–206.29	105	1.05	0–206.29
Rural	9	13.22	0.10–152.46	10	3.25	0.12–51.76	18	8.3	0.12–171.01

population density across three different elements of the stranger crimes: distance from offender's residence to (1) initial contact site, (2) assault/homicide location, and (3) victim release/body disposal location. Overall, results indicated that rural areas were most often associated with offenders travelling further compared to more densely populated urban areas. However, findings differed when exploring stranger homicides and stranger sexual assaults and the different stages of the crimes.

4.1 | Population density

Overall, findings across both stranger sexual assault and stranger homicides showed no significant effects regarding the distance an offender travelled from their residence to the *initial contact* location. This was found across the urban/rural coding, as well as the 5 categories of population density. Although both stranger sexual assaults and stranger homicides showed the highest distance travelled to initial contact site within Rural Village areas (5.23 and 14.19 km, respectively) compared to other categories, the differences were non-significant. Analysis did however, find that in cases of sexual assault Initial contact locations were significantly further from offender's residence than attack or release locations. This may indicate that the initial contact location reflects opportunities that arise within the offender's local area or daily routine, reflecting Rational Choice Theory (RCT) (Cornish & Clarke, 1986), which proposes that offence locations are the result of an interaction between an offender's decision-making process and how they perceive their environment. Linking with Crime Pattern Theory (CPT) (Brantingham & Brantingham, 1981) the initial contact may result from an unexpected opportunity to offend in combination with an offender's routine activities and their environment.

Moving to the attack/homicide location and distance from the offender's residence, homicide locations again yielded non-significant effects across all of the population density categories. Trends could be seen of rural locations showing higher median distances travelled than urban attack locations, but these failed to reach significance thresholds. However, for stranger sexual assaults, offenders' residences were significantly further from rural (4.45 km) compared to urban (1.48 km) sexual assault attack locations. This was further evidenced in the population density categories with Rural Village indicating significantly greater distance travelled (6.73 km) compared to all other lower density areas (≤1.66 km). This indicates that in stranger sexual offences the victim is likely moved from the initial contact site, with offences which occur in rural areas travelling greater distance to this location. THowever, for stranger homicides, there seems to be little difference in distance travelled for initial contact and homicide location. These differences may reflect opportunities to initially meet and move a victim to a safe location in order in to commit the actual offence (Rossmo & Rombouts, 2017).

Notably, victim release/body disposal location showed significant effects for population density across both stranger sexual assaults and stranger homicides. This is important to note when reflecting on the previous findings, where differences were rarely found at initial contact and attack locations. This may indicate the importance of measuring and considering the different key points in a crime and how they may provide different indicators for an offender's JTC. For stranger homicides, the distance an offender travelled to a body disposal location indicated that homicide offenders were more likely to travel further from their residence when disposing of a body in a rural location. The median distance travelled to a rural location was 8.30 km compared to 1.05 km in an urban area. For the Rural Village category, the distance from an offender's residence to body disposal site was 11.2 km, significantly higher than Urban City (0.9 km) and Urban Major Conurbation (1.57 km). For homicide offenders the obvious interpretation of this finding is the importance of concealment of the body and being able to distance themselves from the crime, therefore, requiring this to be in more rural and less densely populated areas which are likely to be some distance from their residence. Further research is required to consider other temporal and spatial factors influencing an offender's decision-making of how far to travel, such as the time of day when the crime was committed (Sea & Beauregard, 2017).

Within stranger sexual assaults and victim release locations, a similar trend to stranger homicides was found with rural victim release sites indicating a significantly greater distance from an offender's residence compared to distances travelled within urban location categories This was most pronounced for Rural Village (5.23 km) compared to Urban City, Urban Minor Conurbation and Urban Major Conurbation (all ≤1.79 km). This finding also reflects the examination of sexual assault location. This finding was further evidenced within the comparisons across the 3 stranger sexual assault locations, which indicated that initial contact location significantly differed (was further from the offender's residence) compared to attack and victim release location (which were both closer to the offender's home). Essentially, this suggests that the sexual offence assault location and victim release site are a similar distance from the offenders' residence, with the initial contact location further away. This may indicate that the assault and victim release location require different considerationsand decision-making from an offender compared to the initial contact in terms of where this should occur relative to the residence and awareness spaces. The emphasis is placed on offenders having *awareness spaces*, which develop from their daily routines and enable offenders to commit serious offences in areas that are familiar to them whilst maximising their encounter with a victim and also minimising potential risks (Rossmo, 2000). Distances travelled are also determined by an offender's access to resources. For example, if an offender does not have access to a car, this will limit the opportunity to transport a body any great distance (Chainey & Ratcliffe, 2005). Interestingly, the finding within stranger sexual assaults indicating differences in median distances across the three offence locations (initial contact, attack and victim release) was not replicated for stranger homicides. It must be noted however, that the initial contact location for homicide is not always known.

4.2 | Limitations and future research

Several limitations should be considered before applying the findings of this research in an operational context. The first concern is the use of archival police recorded data, this data was collected for investigative reasons, not for the purposes of empirically based research (Ter Beek et al., 2010). Although SCAS has access to all the police information it should be acknowledged that sometimes only the offender knows where for example, they first interacted with the victim, what happened within that first interaction if there are no other witnesses, or can only analyses offences where the body has been recovered This missing data may have reduced the validity and reliability of the findings (Ter Beek et al., 2010). However, unlike primary data collection, the use of archival police recorded data is not influenced by researcher bias and contains a higher degree of ecological validity (Canter & Alison, 2003). It should also be noted that there was a great deal of variation in the JTC ranges for different groups; median distances were reported and non-parametric analyses were conducted to reduce the impact this variation would have on the findings of this study. The sample also contained a small number of offences which involved multiple victims, it could be argued that these offenders' decision making may differ from single victim offenders. Therefore, future research would consider these types of offenders separately to explore if there are differences in their JTC.

Data for this research spanned the periods 2000–2019 for sexual assaults and 1990–2018 for homicide. However, the population density of an area was categorised based upon 2011 (England & Wales) and 2016 (Scotland) classification systems. Thus what may have been a rural offence location in 2000 could have been defined as urban through the 2011/2016 classification systems. This is possible as rural areas accounted for 21.35% of the land in the UK in 2000 but dropped to 17.11% in 2016 (Ritchie & Roser, 2019). Nevertheless, it is important that users of this research are aware of some of the limitations associated with such classification systems. Future research should attempt to remedy this by using population density levels from the time of the offence.

A further limitation was that the homicide sample size was relatively small once split by population density category. To increase understanding of the impact of offence locations' population density on JTC, future research should incorporate other variables such as attempts to conceal the body, whether the offender used public transport, and whether a vehicle was used by the offender, as JTC is clearly a dynamic process that is influenced by diverse factors. Future research could explore the type of location in more detail: for example, was it a residence, public or private

space and how might this impact on distance travelled. Interviews could also be conducted with convicted offenders to ask them what decision-making processes they went through when deciding where to offend. Future research should also consider using data from other countries to investigate whether similar patterns are found in offenders' JTC in different geographical and cultural contexts. Further work could be undertaken on the relationship between the different crime sites, not just the distance from the offender's residence, in order to understand the offence as a whole event.

4.3 | Conclusion

This research was of value as the exploration of how environmental factors such as population density may impact JTC was very limited in the literature. Within the current study, it was clear that a key stage within these serious stranger offences was body disposal/victim release. Results highlighted that the key stages of the offence require consideration of the different geographical factors for the offence to be completed, with body disposal/victim release sites needing less populated areas, compared to initial contact or attack sites. In addition, within stranger sexual assaults results indicated that initial contact location was significantly further from an offender's residence when compared to attack and victim release site, with no differences found within stranger homicides. Again, this illustrates the need to understand how location changes across the commission of an offence for some crimes (such as stranger sexual assault), alongside factors such as population density at these key crime sites.

It is hoped the findings of this research can assist the investigation of stranger sexual offences and stranger homicides. Importantly this research provides empirically based findings for Geographic Profilers, who currently rely on generic JTC research, to conduct their work. Therefore, despite the limitations associated with the research it provides information that will allow Geographic Profilers to generate better supported inferences about an offender's JTC based upon the location of the crime-sites to assist police investigations in difficult to solve cases.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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ENDNOTE

[1] Where the offender is a stranger to the victim or where the relationship between them is unknown

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